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Multilayered Steel Armour

Field of the Invention

The invention relates to the multilayered steel armour for both the defense and civilian ballistic protection application.

Background of the Invention

The techniques of armouring applied both in civilian and defense realms make use of the various monolithic and/or composite steel armours in the role of assembly components and parts. Hand in hand with the ever-increasing requirements of the degree of the ballistic protection the technical capacity to meet such requirements has become virtually exhausted when only monolithic armour materials are concerned and therefore we have been recently witnessing a gradual shift of emphasis towards the application and use of two-layered materials bonded together.

These two-layered steel armour plates are usually made from a suitable combination of two kinds of materials having quite different properties. The front-face layer intended to break or shatter attacking bullets is usually made from the steel of very hihg hardness containing, for example, 0.5 wt% to 1.5 wt% of carbon, 0.2 wt% to 2.0 wt% of manganese, 0.1 wt% to 1.5 wt% of silicone, 0.2 wt% to 8.0 wt% of chromium, 0.1 wt% to 4.0 wt% of nickel, 0.2 wt% to 6.0 wt% of tungsten, 0.05 wt% to 0.5 wt% vanadium and the rest being iron and other accompanying elements and impurities.

The backing layer is formed by the more conventional armour steel material, intended to absorb remainder of bullet and fragments kinetic energy with a higher toughness containing, for example, 0.2 wt% to 0.6 wt% of carbon, 0.3 wt% to 2.0 wt% of manganese, 0.1 wt% to 2.0 wt% of silicone, 0.1 wt% to 3.0 wt% of chromium, 0.2 wt% to 4.5 wt% of nickel, 0.1 wt% to 1.0 wt% of molybdenum and the rest being iron and other accompanying elements and impurities. These two-layered plates are produced using technology of explosive cladding (high-velocity impact cladding) or by rolling together the individual layers at elevated temperature, wide-area welding techniques, by casting and successive pressure forming or by welding the initial semi- finished products under the molten welding flux and other similar technologies.

The common disadvantage of all these two-layered steel armour plated is the widely different physical and technological properties of the front and the backing layer resulting in a considerable and undesirable changes of shape of the two-layered armor plates taking place both during their manufacturing process giving the plates the basic shape and during the thermal treatment of the completed and deployed armor. Another and very serious disadvantage of these two-layered armor plates is an ease with which the cracks are able to propagate themselves through the mass of the armour material once under a severe ballistic load.

The armours containing three and more layeres are also known from existing patents, but described problems are there solved only partially.

For example, in EP 0 247 020 A1 a multilayered armour plate is produced using the technology of cladding with an intermediate layer inserted between its front-face layer and the backing layer. This intermediate layer is made from pure nickel or pure iron stabilized by titanium or niobium, with maximum 0,01 wt% of carbon and the thickness between 0,1% and 15% of total thickness of the armour plate.

In DE 43 44 711 A1, a protective plate is produced from several individual plates of the same thickness, made typically from austenitic steels alloyed by nitrogen and bonded together by spot welding, eventually using cladding and gluing. This solution, however, is oriented only to elimination of danger of brittle fracture, all layers having the same composition and no joining intermediate layer of different composition and thickness being present.

A multilayered armour is also known from US 2003/0159575 A1, where the invention is based on application of binary materials with shape memory, eventually materials exhibiting temperature-dependent reversible phase change, that absorbs energy through austenitic-martensitic transformation and/or an elastic strain deformation of at least 5%. They are typically on the base of titanium and its alloys containing at least 50 wt% of titanium.

The better joining of the front-face ballistic layer and backing layer during rolling is solved in FR 2 106 939. The corresponding invention is based on the galvanical deposition of the layers of iron or nickel on the joining surfaces of the multilayered armour which is made from common materials. Considering that thickness of the layers created during galvanic processes is of the order of micrometers, the patent deals effectively with two-layered armour without any interlayer with ballistic function and galvanic preprocessing represents common technological method used before roll welding.

The present invention extends the assortment of multilayered steel armours with emphasis on the compactness and the flatness, the stability of the joining metallic interlayers, which prevent the crack propagation from the hard and brittle front-face layer to the backing armour layer ensuring higher toughness and high ballistic endurance of the whole armour and, at the same time, increasing the effectiveness of its production.

Summary of the Invention

The disadvantages associated with existing multilayered techniques of armour design and manufacturing are to a great extent eliminated by the multilayered steel armour consisting of the front-face ballistic-resistant armour layer and the backing armour layer, which are fully on the whole

surface metallurgically bonded by means of at least one joining metallic intermediate layer, for example, by casting, wide-area welding techniques, using technology of explosive cladding (high-velocity impact cladding), by roll welding or by combination of the previous techniques, according to the invention. The invention is based on the fact, that the joining metallic intermediate layer between front-face ballistic-resistant armour layer and backing armour layer is made from the material featuring the face-centered cubic crystalline lattice (FCC lattice), in particular, from the nickel alloy containing maximally 98.0 wt% of nickel and/or from steel.

The FCC metallic material of the joining metallic intermediate layer used in the sandwich can be preferably, for example, nickel alloys containing from 50.0 wt% to 98.0 wt% of nickel and from about 0.1 wt% to 45.0 wt% of at least one metal from the group of alloying elements such as chromium, molybdenum, manganese, niobium, titanium, iron and the rest formed by other accompanying elements and usual impurities.

Another convenient arrangement of the invention represents the material of the joining metallic intermediate layer comprising between 5.0 wt% to 50.0 wt% of nickel, in total between 0.1 wt% to 40.0 wt% of chromium, manganese, molybdenum, niobium and titanium serving in the role of alloying admixtures while the reminder is formed by iron and some other usual additional elements and impurities.

In addition to the above-described compositions, the other convenient material of the joining metallic intermediate layer according to the invention is the alloy containing from 8.0 wt% to 30.0 wt% of manganese and altogether 0.1 wt% to 30.0 wt% of alloying admixtures of chromium, nickel, vanadium, silicone and carbon while the reminder represents iron and other accompanying elements and impurities.

Specifically, the material of the joining metallic intermediate layer can be also the well known austenitic nickel steel alloys containing more than 20.0 wt% of nickel and the possible combinations of the known austenitic chromium-nickel alloys containing typically 18 wt% of chromium and 8 wt% of nickel. The other possible option for the composition of the intermediate layer is the known austenitic manganese alloys like for example the Hadfield Steel with more that 12 wt% of manganese content.

The thickness of the joining metallic intermediate layer can be conveniently set from 0.5 % to 25 % of the total thickness of the steel armour according to the invention. The thicknesses of the external front-face ballistic-resistance armou layer exposed to ballistic loads and the backing armour layer can be either equal to each other or they can differ to achieve the most convenient properties of the sandwich as the whole.

The basic configuration of the invention represents the multilayered steel armour formed by just the three layers, i.e. the sandwich with the simple joining metallic intermediate layer placed between the front-face ballistic-resistant armour layer and the backing armour layer.

However, the alternative implementation of the herein invention can use more that just these three basic layers. Between the front-face ballistic-resistant armour layer and the backing armour layer at least one more extra internal armour layer is inserted. If this is the case, all the inserted internal armour layers are joined and sandwiched together using the above described joining metallic intermediate layers as per herein described invention.

The inserted internal armour layers used to achieve the most convenient properties of the entire structure are made from steel containing 0.2 wt% to 0.9 wt% of carbon, 0.1 wt% to 2.0 wt% of manganese, 0.2 wt% to 2.0 wt% of chromium, 0.3 wt% to 4.5 wt% of nickel, 0.1 wt% to 1.0 wt% of molybdenum 0,1 wt% to 2.0 wt% of silicon and no more than about 0.01 wt% of boron, the reminder being iron and other accompanying elements and impurities.

When implementing this alternative mode of the hereby described invention the thicknesses of the inserted internal armour layers can be either equal to each other or they can mutually differ and the sum total of the thicknesses of all inserted armour layers and the corresponding joining metallic intermediate layers represents 1.5 % to 60 % of the total thickness of multilayered steel armour according to the invention.

The multilayered steel armour made to the specifications of the herein described invention result into compact armour structure with extremely high level of adhesion, strong metallurgical bond of the individual layers. The advantages of such composed structures manifest themselves in particular during giving these materials desired shape and during the thermal treatment of these materials and products. The joining metallic intermediale layer (or layers as case may be) due to their high plasticity eliminates deformations due to structural, thermal and dimensional changes taking place in the individual armour layers.

In addition to the above advantage of the multilayered steel armour according to the invention the other substantial advantage of these armoured plates manifest itself in the realm of their ability to withstand extremes of ballistic loads. The joining metallic intermediate layer represents an efficient barrier in the way of propagation of cracks between the individual armour layers whereby significantly enhancing the overall structural integrity of the armour.

The multilayered steel armour can be created using all the known and widely used technologies such as multilayered casting and forming, plating, cladding, welding, rolling at elevated temperatures, etc.

Brief Description of the Drawings

The invention will be further clarified in more detail using the schematic drawings, where is:

Fig. 1 - multilayered steel armour with three layers
Fig. 2 - multilayered steel armour with seven layers

Description of the Prefered Embodiment

Example 1

Multilayered steel armour according to this example, as in Fig. 1, comprises from the front-face ballistic-resistant layer 1 and from the backing armour layer 2.

The front-face ballistic-resistant armour layer 1 is made from steel alloy containing 0.66 wt% of carbon, 0.40 wt% of silicone, 0.40 wt% of manganese, no more than about 0.010 wt% of phosphorus, no more than about 0.010 wt% of sulfur, 1.20 wt% of chromium, 0.20 wt% of nickel, 0.20 wt% of vanadium, 1.90 wt% of tungsten, while the rest is iron and other accompanying elements and impurities.

The backing armour layer 2 is made from the steel alloy containing 0.30 wt% of carbon, 1.60 wt% of silicone, 1.40 wt% of manganese, no more than about 0.010 wt% of phosphorus, no more than about 0.008 wt% of sulfur, 0.40 wt% of chromium, 1.20 wt% of nickel, the rest is iron and other accompanying elements and impurities.

There is the joining metallic intermediate layer 3 located between the front-face ballistic-resistant armour layer 1 and the backing armour layer 2. This joining metallic intermediate layer 3 is the austenitic FCC crystalline lattice structure containing 71.0 wt% of nickel, 16.0 wt% of chromium, 3.0 wt% of manganese, 1.0 wt% of molybdenum, 2.0 wt% of niobium, 6.0 wt% of iron and the rest being the accompanying elements and common impurities.

The overall thickness t of this multilayered steel armour is 10 millimeters. The thickness t_1 of the front-face ballistic-resistant armour layer 1 is 4.7 millimeters, the thickness t_2 of the backing armour layer 2 is also 4.7 millimeters and the thickness t_3 of the joining metallic intermediate layer 3 is 0.6 millimeters, which represents 6 % of the overall thickness t of the multilayered steel armour.

The multilayered steel armour of this example is manufactured using the technology of explosive cladding and subsequent rolling at elevated temperature.

Example 2

Multilayered steel armour in this example represents the alternative implementation of the multilayered steel armour from the first example with the changed material of the inserted joining metallic intermediate layer 3. The material of this layer 3 was changed to the austenitic structure containing 10.6 wt% of nickel, 16.7 wt% of chromium, 2.2 wt% of molybdenum, 1.7 wt% of manganese, 0.5 wt% of silicone, 0.4 wt% of titanium, 0.03 wt% of carbon with the rest being iron

and other usual admixtures and impurities.

This multilayered steel armour is prepared using the technology of multilayered casting, which is followed by the elevated temperature rolling process. The total thickness t of this multilayered steel armour is 7.5 millimeters, the thickness t_1 of the front-face ballistic-resistance armour layer 1 is 3.5 millimeters, the thickness t_2 of the backing armour layer 2 is 3.6 millimeters and the thickness t_3 of the joining metallic intermediate layer 3 is 0.4 millimeters, representing 5.3 % of the overall thickness t of the steel armour.

Example 3

The multilayered steel armour in this (third) example also represents the alternative implementation of the multilayered steel armour of the type introduced in the example 1. The difference is in a different composition of the joining metallic intermediate layer 3 joining the armour layer 1,2. The material of this layer 3 is the austenitic structure containing 12.5 wt% of manganese, 1.3 wt% of carbon, 0.4 wt% of silicone while the rest is iron, other accompanying elements and usual impurities.

The total thickness t of this multilayered steel armour as well as the thickness t_1 of the front-face ballistic-resistant armour layer 1 and the thickness t_2 of the backing armour layer 2 and finally the thickness t_3 of the joining metallic intermediate layer 3 are identical to thicknesses of the example 2.

Example 4

The multilayered steel armour, as in Fig. 2 is formed by the front-face ballistic-resistant armour layer 1 and the backing armour layer 2, having the same chemical composition as the corresponding layers 1,2 of the example 1. Between the front-face ballistic-resistant armour layer 1 and the backing armour layer 2 are sandwiched two additional internal armour layers 4 and 5 and the corresponding joining metallic intermediate layers 3, which are located between all the armour layers 1,2,4,5 present in the sandwich.

The joining metallic intermediate layers 3 are the austenitic FCC crystalline structures containing 9.0 wt% of nickel, 17.5 wt% of chromium, 1.9 wt% of manganese, 0.6 wt% of silicone, 0.4 wt% of titanium, 0.06 wt% of carbon, while the rest being iron and the common accompanying elements and impurities.

The first inserted internal armour layer 4 is formed by the steel alloy containing 0.45 wt% of carbon, 0.70 wt% of manganese, 0.23 wt% of silicone, 0.50 wt% of chromium, 2.0 wt% of nickel, 0.35 wt% of molybdenum while the rest is iron and other common accompanying elements and impurities.

The second inserted internal armour layer 5 is formed by the steel alloy containing 0.26 wt% of carbon, 1.0 wt% of manganese, 1.19 wt% of silicone, 0.37 wt% of chromium, 0.95 wt% of nickel, 0,27 wt% of molybdenum, 0.006 wt% of niobium while the rest is iron and other common accompanying elements and impurities.

The total thickness $\underline{t}$ of the steel armour is 12.0 millimeters. The thickness $\underline{t}_1$ of the front-face ballistic-resistant armour layer 1 is 3 millimeters and the thickness $\underline{t}_2$ of the backing armour layer 2 is also 3 millimeters. The thicknesses of all joining metallic intermediate layers 3 are 0.4 millimeters. The thickness $\underline{t}_4$ of the first internal armour layer 4 is 2.5 millimeters and the thickness $\underline{t}_5$ of the second internal armour layer 5 is 2.3 millimeters. Thus, the sum total of the thicknesses $\underline{t}_3$ of all inserted joining metallic intermediate layers 3 and the thicknesses $\underline{t}_4$, $\underline{t}_5$ of the two inserted internal armour layers 4 and 5 is 6.0 millimeters, i.e. 50 % of the total thickness $\underline{t}$ of the multilayered steel armour.

The multilayered steel armour presented in this example was produced using the technology of welding of its individual armour layers 1,2,4 and 5 together with the joining metallic intermediate layers 3 and subsequent rolling of the sandwich at elevated temperature.

Field of the Aplication

Multilayered steel armour plates produced in accordance with the herein presented invention find a wide variety of applications especially in products of defense industry where the prime interest is to ascertain the high level of ballistic resistance of the armoured parts and simultaneously maintaining their structural integrity.